Towards joint morphometry of white matter tracts and gray matter surfaces

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1 Introduction

Morphological studies of anatomical structures play an important role in neuroimaging. For example in the analysis of the circuits connecting sub-cortical areas to the cortical surface one would like to study together gray matter surfaces and white matter tracts (fiber bundles). To the best of our knowledge, there is no generic method to study these objects together.

Atlas construction is based on the joint estimate of a common "mean shape" (template) and of its deformation towards each shape of the population. The atlas shows the invariants of the population and their variability.

We propose a new atlas construction method based on currents [1] which permits to deal with curves and surfaces together. We extend to curves the methodology proposed in [3] for surfaces. This allows to fix a topologically correct representation of the bundle templates. We are therefore able to compare the templates directly with the shapes of the population and to study the relative positions of different objects.

Moreover every deformation is based on one single diffeomorphism of the whole 3D space which preserves the spatial organization of the objects making possibile a joint analysis of multiple objects.

2 Methods

Given a population of N subjects, the aim of this method is to estimate simultaneously the template complex and its deformations towards the N shape complexes. These complexes gather together all the objects under examination. The number of deformations is equal to the number of subjects. Every deformation is based on one single diffeomorphism which is built using a finite set of control points shared among the population. The deformation parameters are given by initial momenta linked to the control points. Thus, the number of control points defines the dimension of the parameterization of the deformations.

The method proposed here is based on the minimization of a cost function achieved with a gradient descent method. We need therefore an initial template complex. We choose an ellipsoid for the surfaces and we propose a new generic method for the bundle templates by selecting the most representative fibers among all the subjects present in the population with a greedy approximation method based on the framework of currents (see Fig.1).

This differs from a previous atlas method for curves based on currents [2] where the templates were not given as fiber bundles, thus making difficult the analysis of the relative position between different objects.

We apply our new method on two populations, one of 5 controls and one of 5 patients with Gilles de la Tourette syndrome [4]. For each population the data set consists of the left globus pallidus (lGP) and the bundle of fibers connecting the globus pallidus to the cortical surface (BGP). Their segmentation was performed from T1-weighted MRI and DWI respectively [5].

3 Results

The final estimated template complex for both populations and the initial template complex are shown in Fig.1. The topology of the initial template complex has been preserved throughout the atlas construction. The comparison between the two updated template complexes reveals the differences between the common features of the two populations.

In Fig.2 we show the updated template complex of the population of controls with the initial momenta of each subject.

We perform also two PCA on the deformation parameters of each population. Fig.3 shows the first mode for both populations at $\pm\sigma$. The main variability in the controls is represented by a torque of BGP and lGP towards the posterior part of the brain while in the patients there is mainly a shrinkage/elongation of both BGP and lGP in the upper part of the lGP.

4 Conclusions

We proposed a new atlas construction method which permits the joint analysis of white matter tracts and gray matter surfaces in a way which preserves their topology in the templates. This method allows the study of the relative positions of different objects while respecting their underlying anatomical organization.

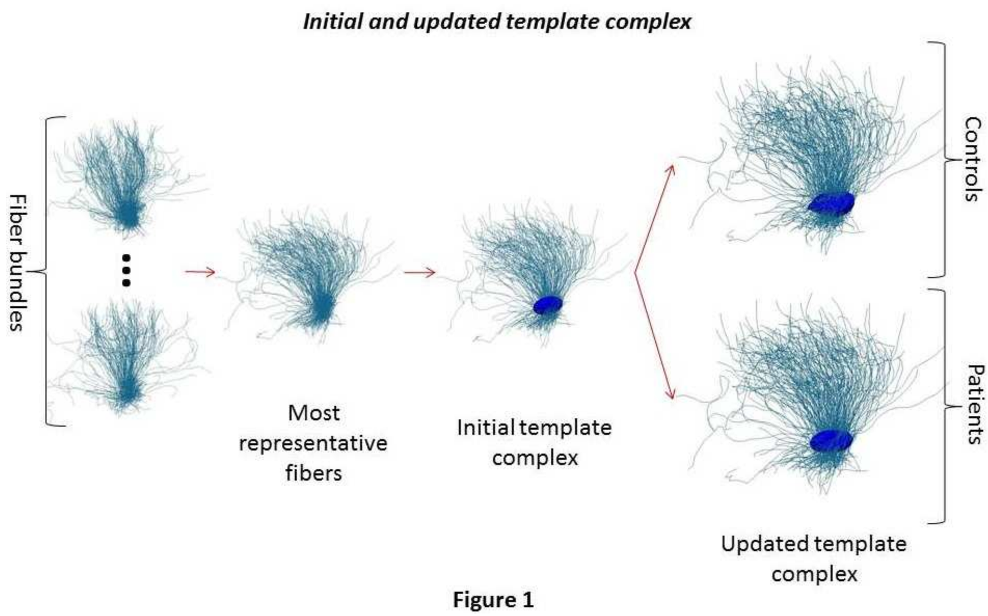

Figure 1

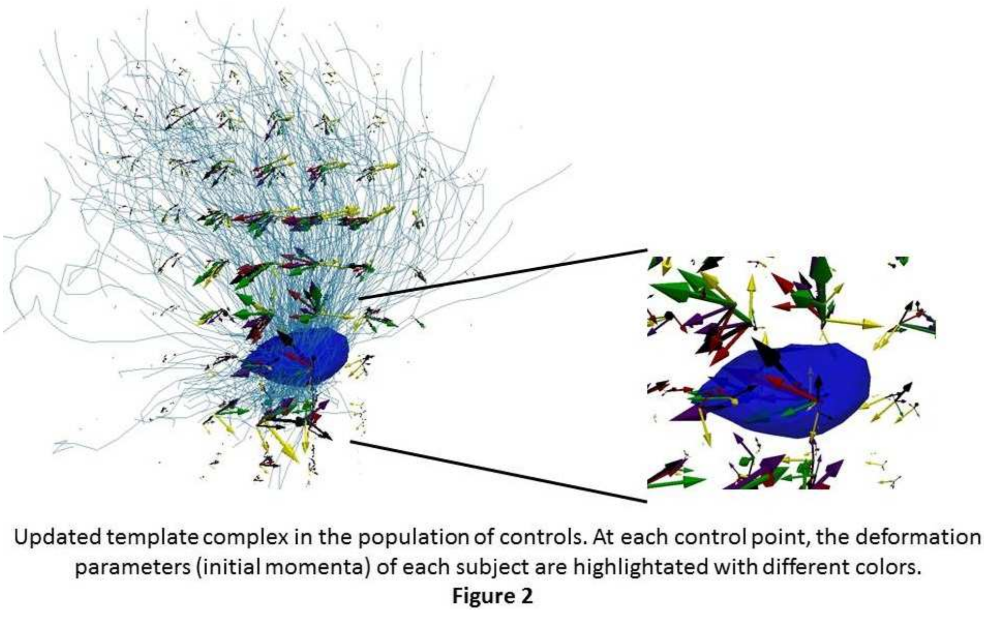

Figure 2

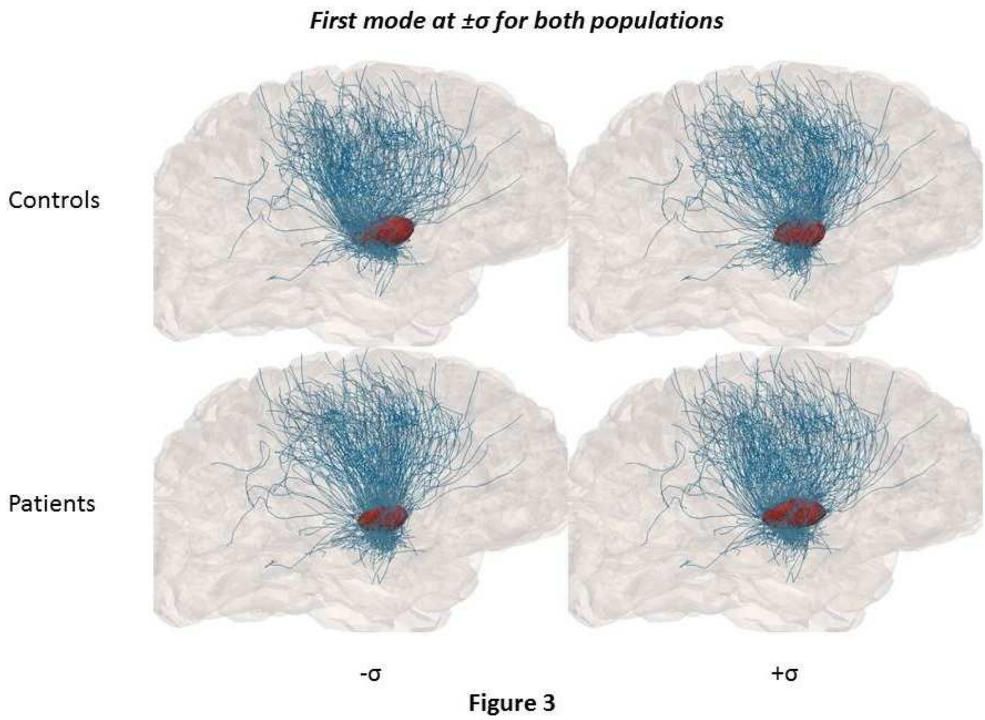
First mode at ±σ for both populations
Controls
Patients
-σ
+σ
Figure 3

Figure 3

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